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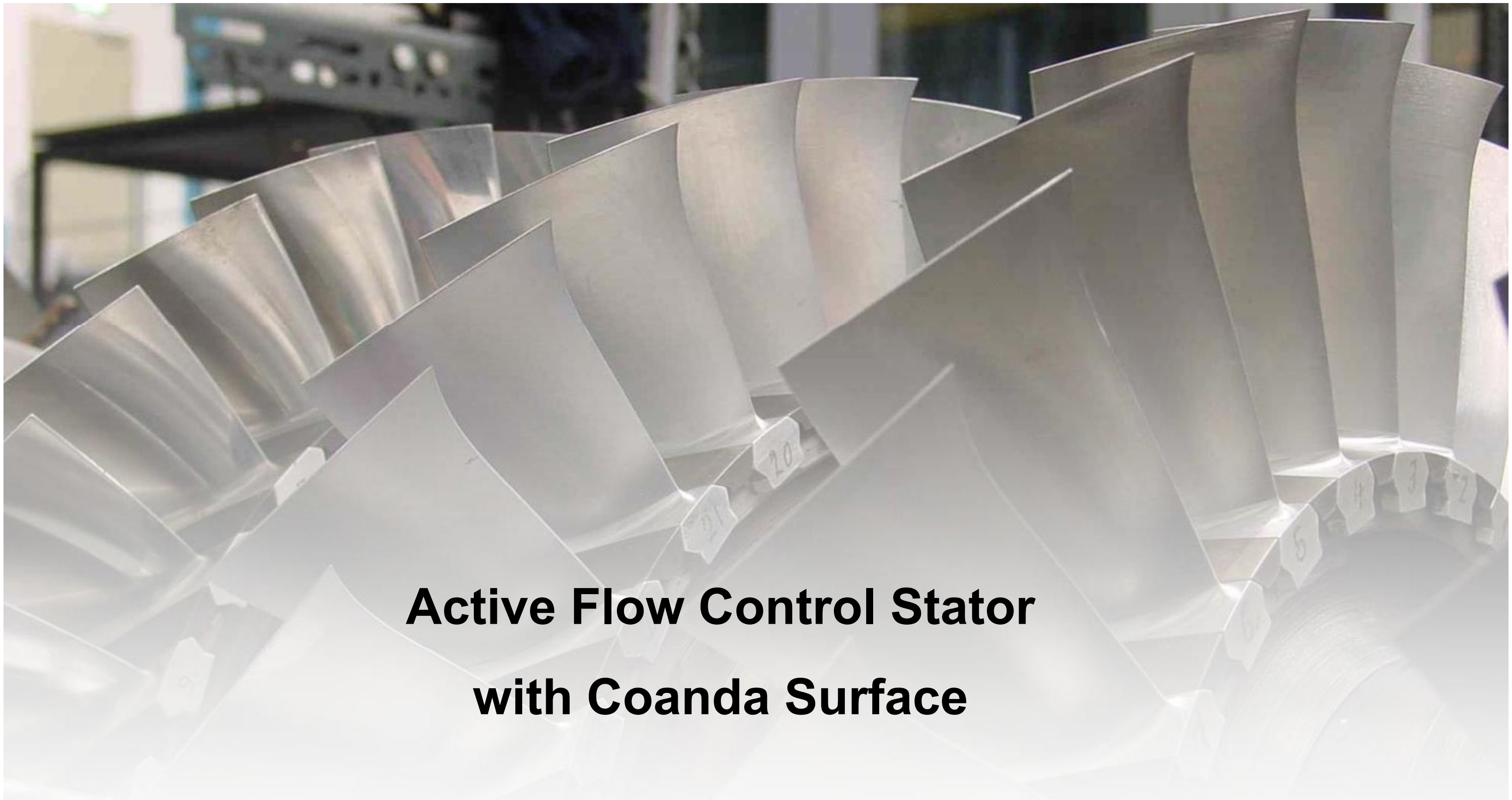

Active Flow Control Stator with Coanda Surface

DESIGN OF A LOW SOLIDITY FLOW-CONTROL STATOR WITH COANDA SURFACE IN A HIGH SPEED COMPRESSOR

Guendogdu, Vorreiter, Seume

Prof. Dr. Seume
Institute of Turbomachinery and Fluid Dynamics

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AFC Stator with Coanda Surface

Introduction:

- Active Flow Control increases the permissible aerodynamic loading
- Curved surface near the trailing edge (“Coanda surface”)
  - increases turning → higher pressure ratio
  - controls boundary layer separation → increased surge margin

Objective:

Reduce the number of vanes or compressor stages.

Constraints:

1. In a real compressor, the vane must still function entirely without blowing.
2. Maintain the flow exit angle of the reference stator despite the resulting increase in stator loading.

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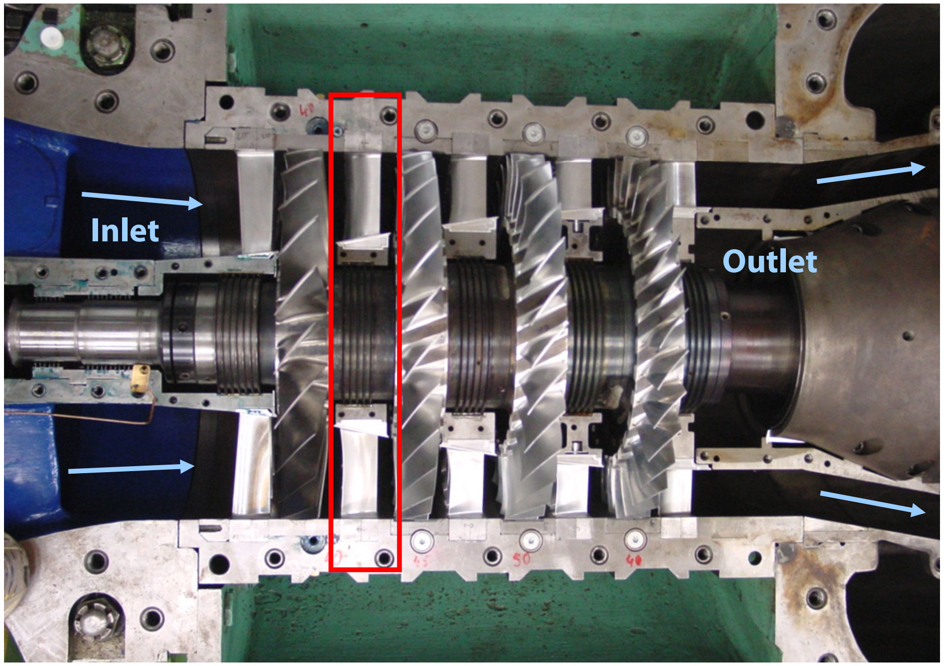
Compressor test rig at TFD
Performance Data



Design speed	17100 rpm
Mass flow	7.81 kg/s
Total pressure ratio	2.75
Isentropic efficiency	90.5%

Power	950 kW
Flow coefficient 1st stage	0.71
Loading 1st stage	0.44
Reynolds number (stator 1)	4×10^5

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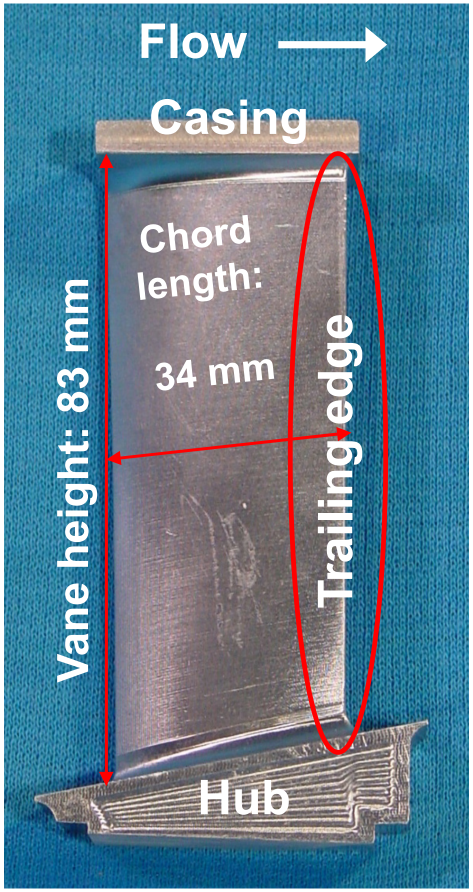
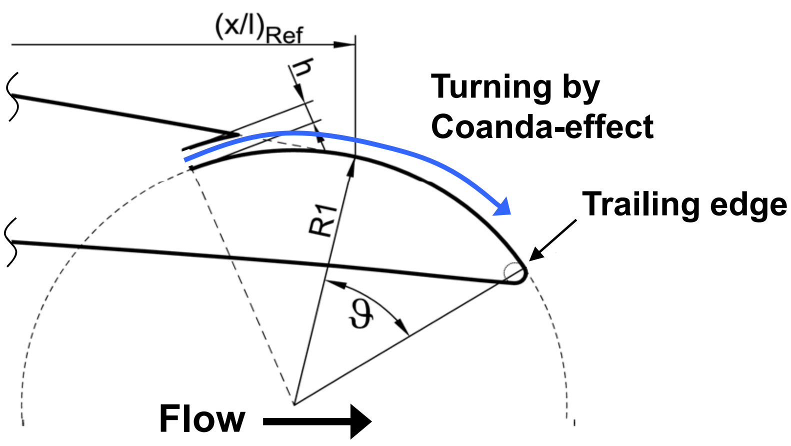
Concept and Design of the Coanda Stator

Definition of the Coanda Surface at the Trailing Edge





• Chord length in mid-span, Stator 1:	l = 34 mm
• Thickness to chord ratio:	8%
• Slot height	h = 0.2 mm
• Slot height/Coanda-radius:	h/R1 = 2%
• Coanda-radius:	R1 = 10 mm

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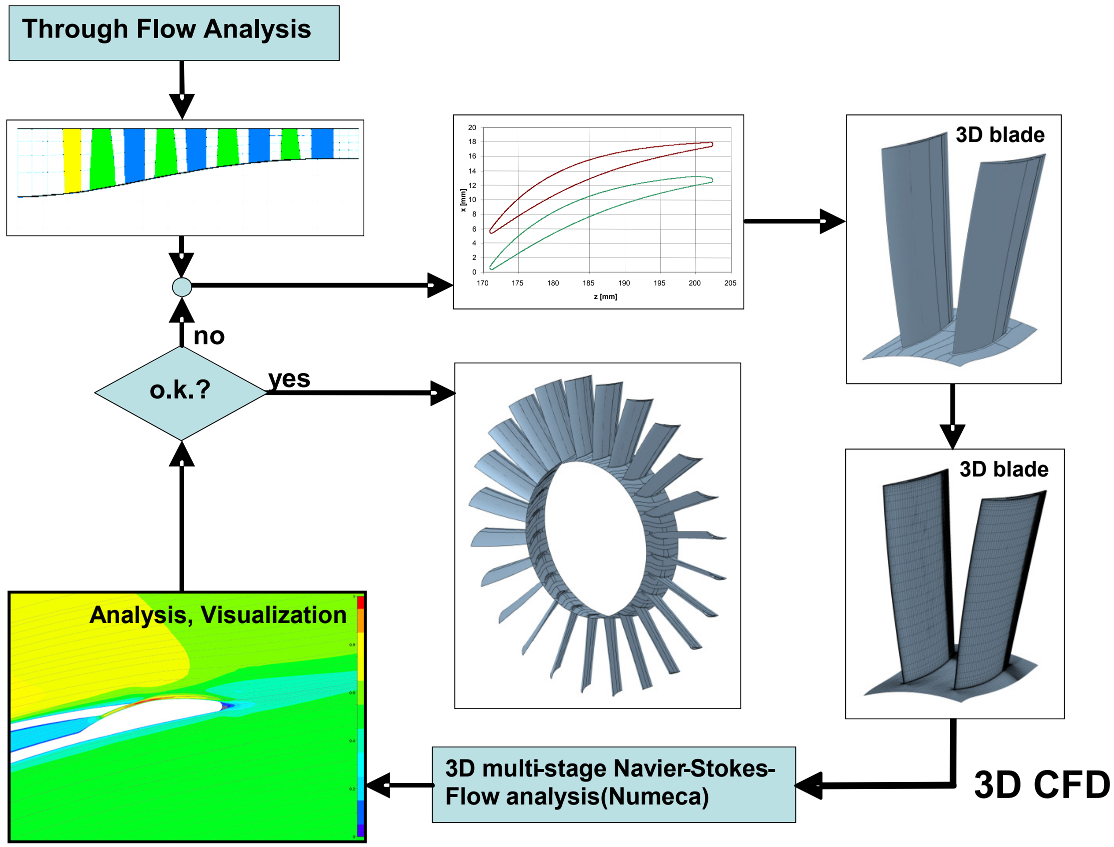
Concept and Design of the Coanda Stator

Basic Design Loop



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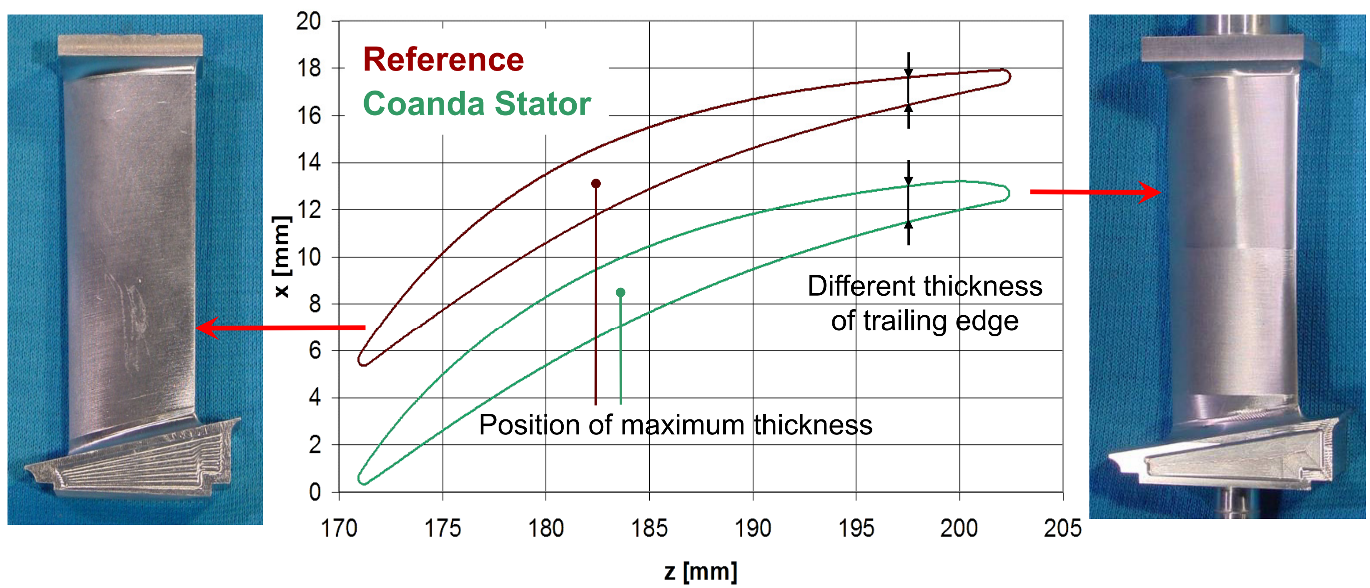
Concept and Design of the Coanda Stator

Profile Section in Mid-Span: Reference and Coanda Stator

Reference **Coanda Stator**



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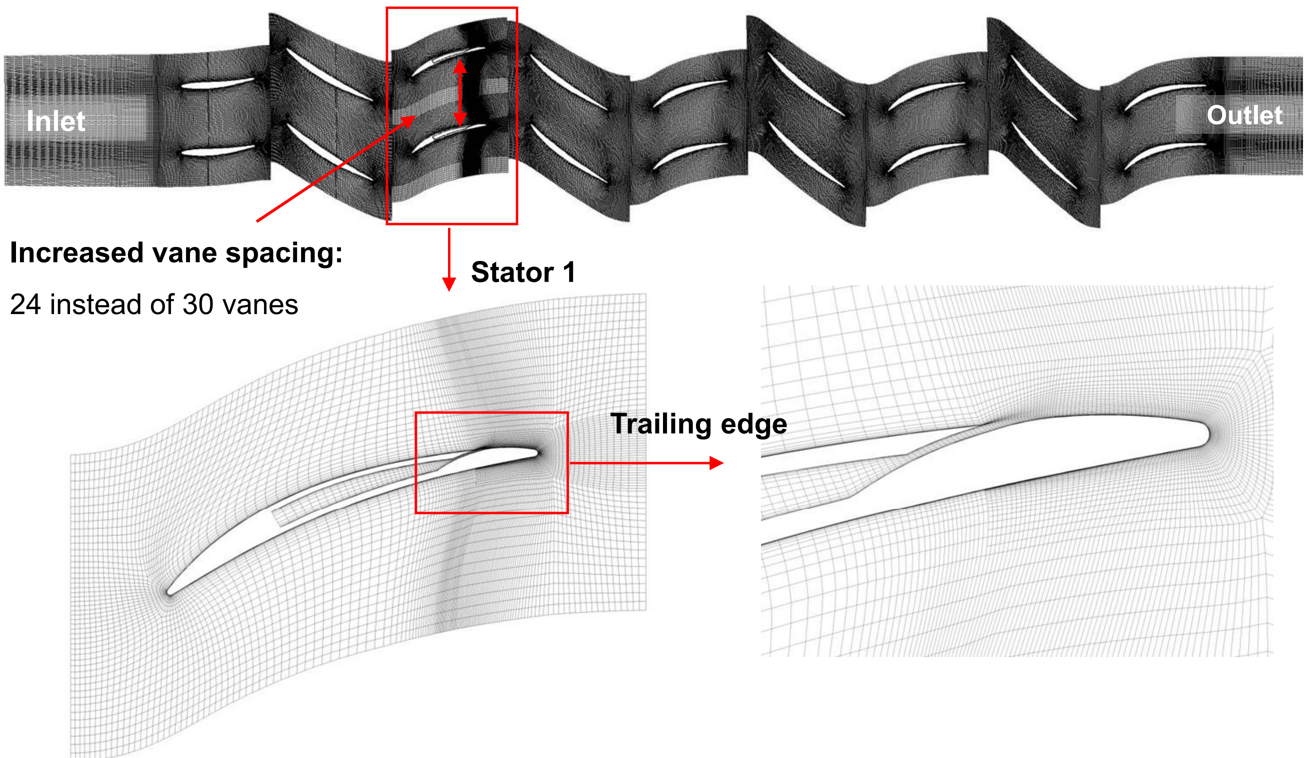
3D CFD Simulations

Mesh for 3D CFD Simulations: Plenum + Slot



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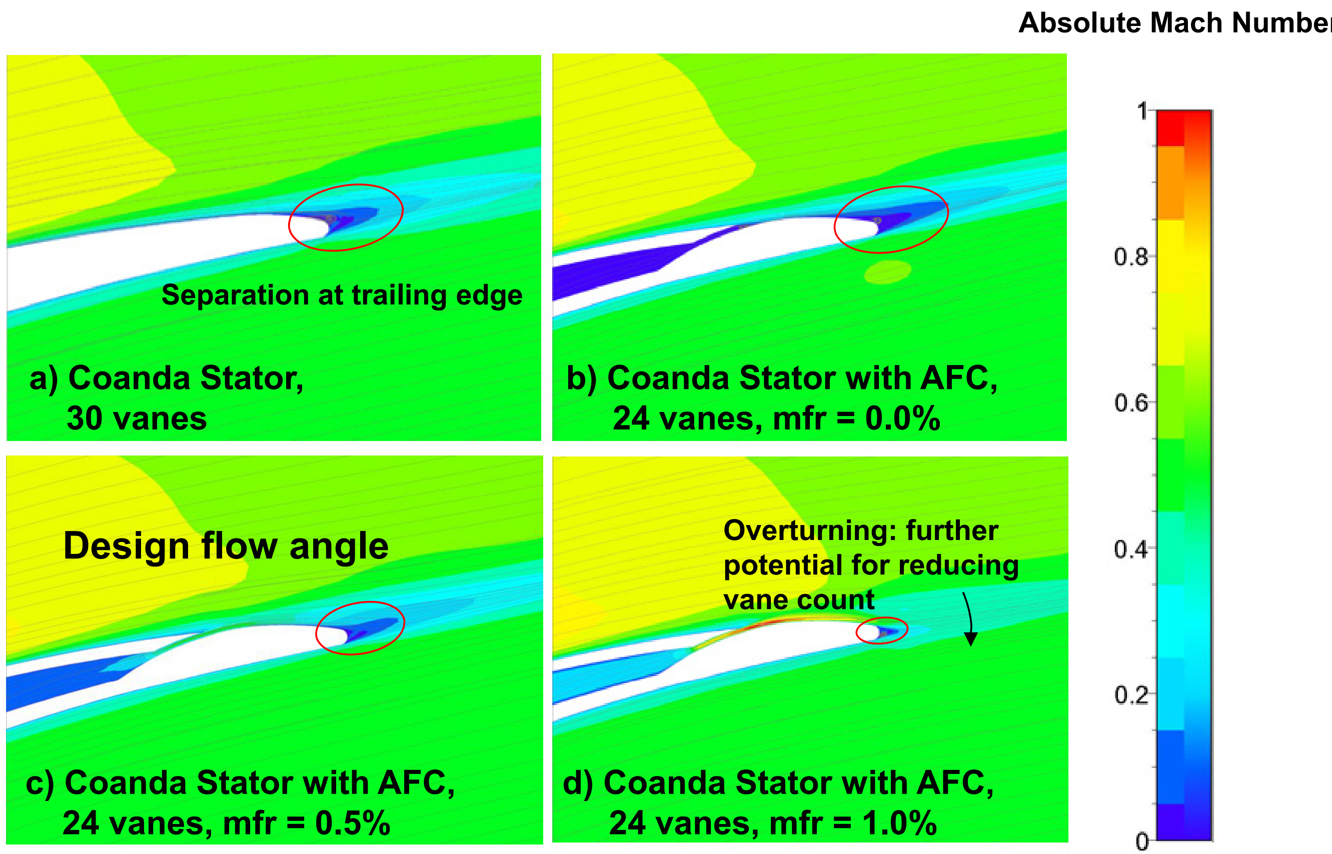
3D CFD Simulations

Mach Number Distribution around Trailing Edge at Mid-Span



Blowing rate: mass flow ratio (mfr) = jet flow / main flow

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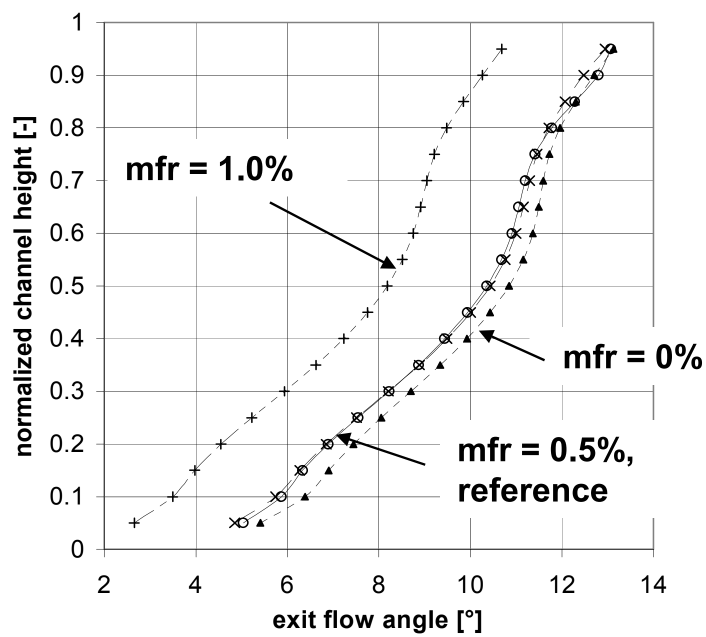
3D CFD Simulations

Radial Distribution of the Exit Flow Angle



→ Reduction of Compressor Stages

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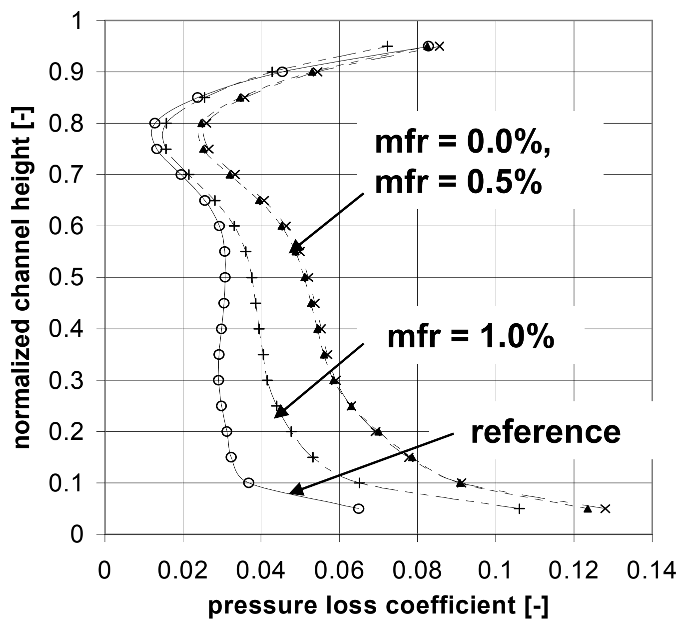
3D CFD Simulations

Radial Distribution of Total Pressure Loss Coefficient



$$\omega = \frac{p_{tot,1} - p_{tot,2}}{p_{tot,1} - p_{stat,1}}$$

Note: **momentum of injected flow not accounted for**

Reduction of Losses → Higher Efficiency

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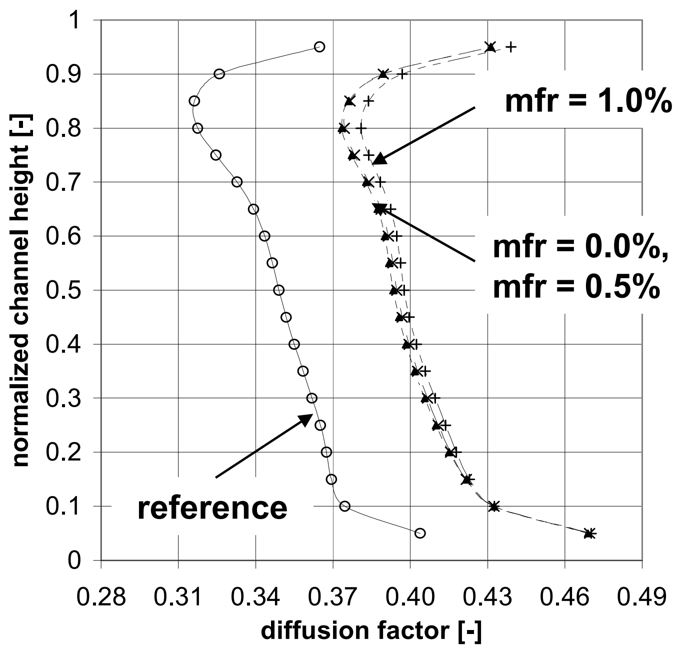
3D CFD Simulations

Radial Distribution of the Diffusion Factor



$$Df = 1 - \frac{w_2}{w_1} + \frac{v_{\theta 2} - v_{\theta 1}}{2\sigma w_1}$$

Increased Permissible Aerodynamic Loading by 13% at the Design Point
→ Better Part Load Performance?

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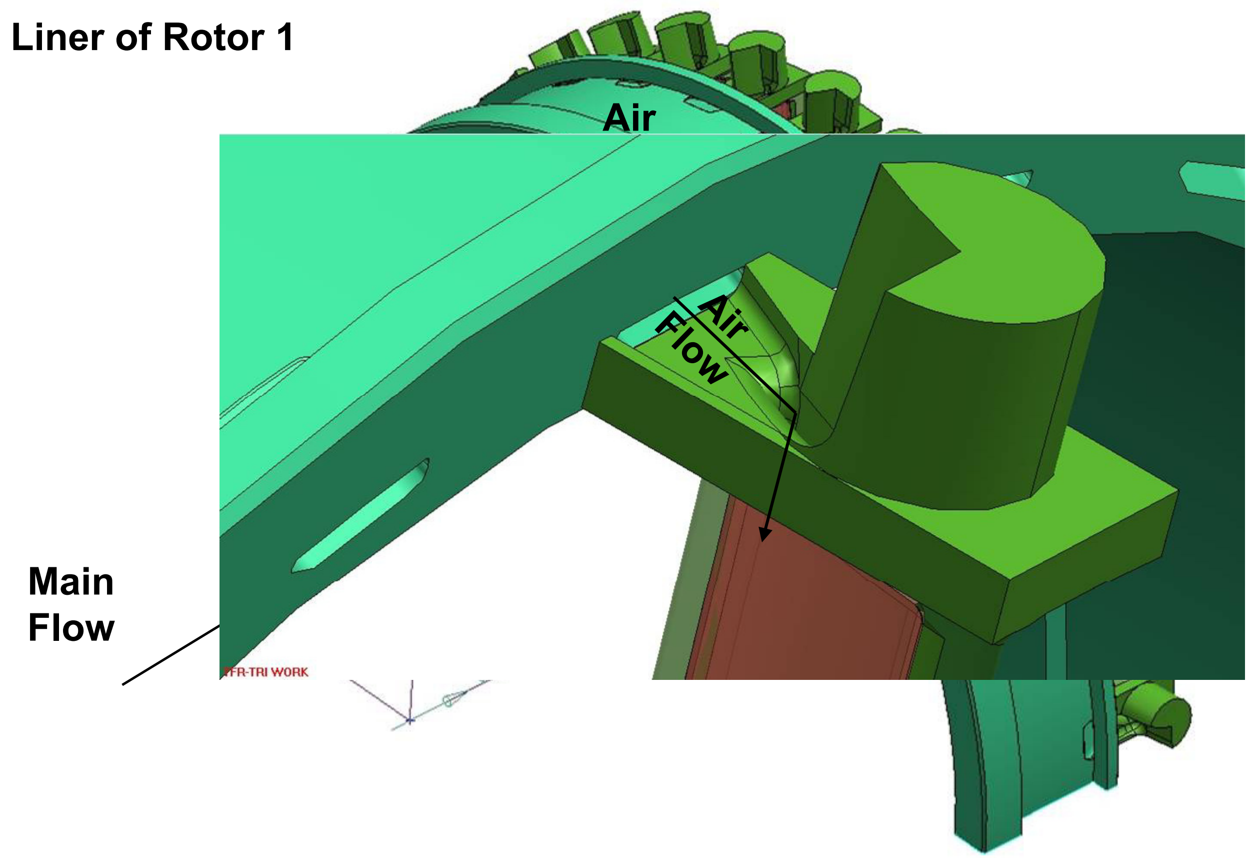
Design, Manufacture and Integration in Compressor

Air Supply for Flow Control Stator



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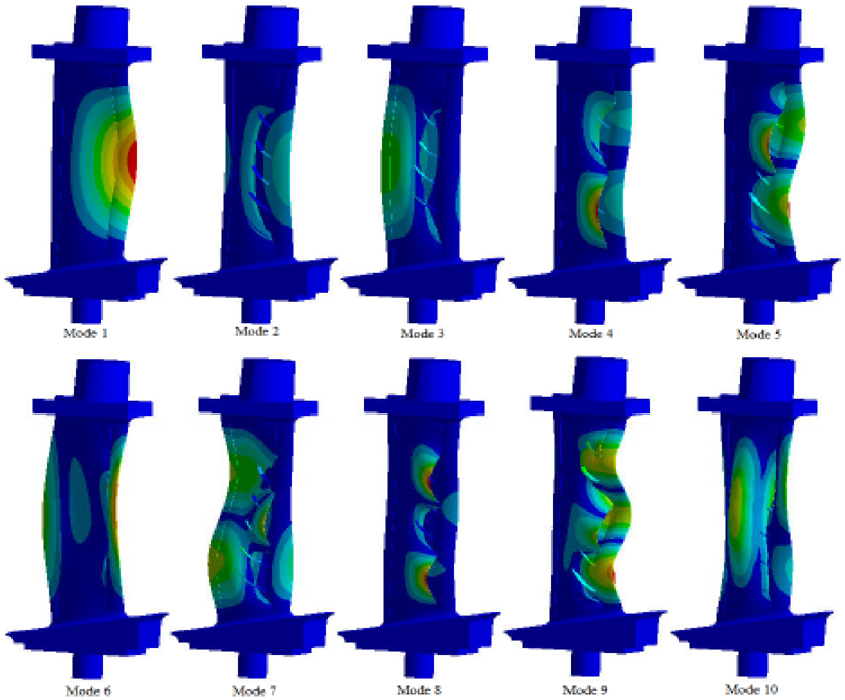
Design, Manufacture and Integration in Compressor

FEM-Modal Analysis of Coanda Stator



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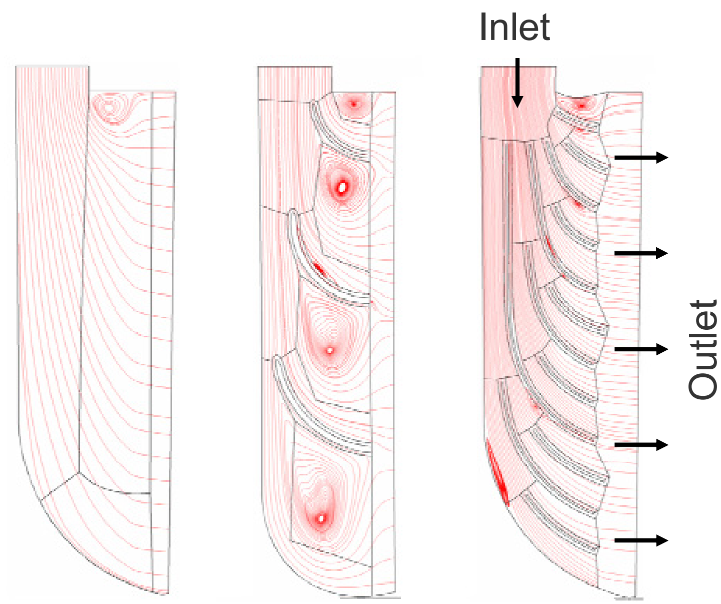
Design, Manufacture and Integration in Compressor

Iterative Design of Plenum in Coanda Stator



Aerodynamics: loss-minimized flow in plenum of Coanda stator

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Design, Manufacture and Integration in Compressor

Coanda Stator

- Two parts: vane body and cover
- Laser welded: low warpage; durable and leak-proof
- Seamless surface: finish after welding

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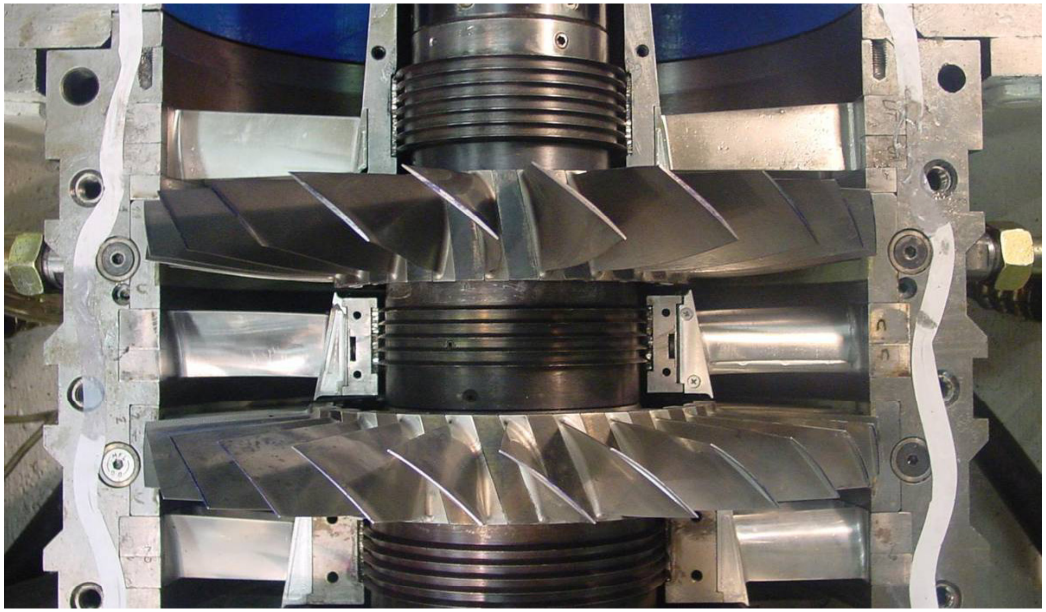
Design, Manufacture and Integration in Compressor

Coanda Stator in First Stage of Compressor



No change of geometry except for Coanda Stator

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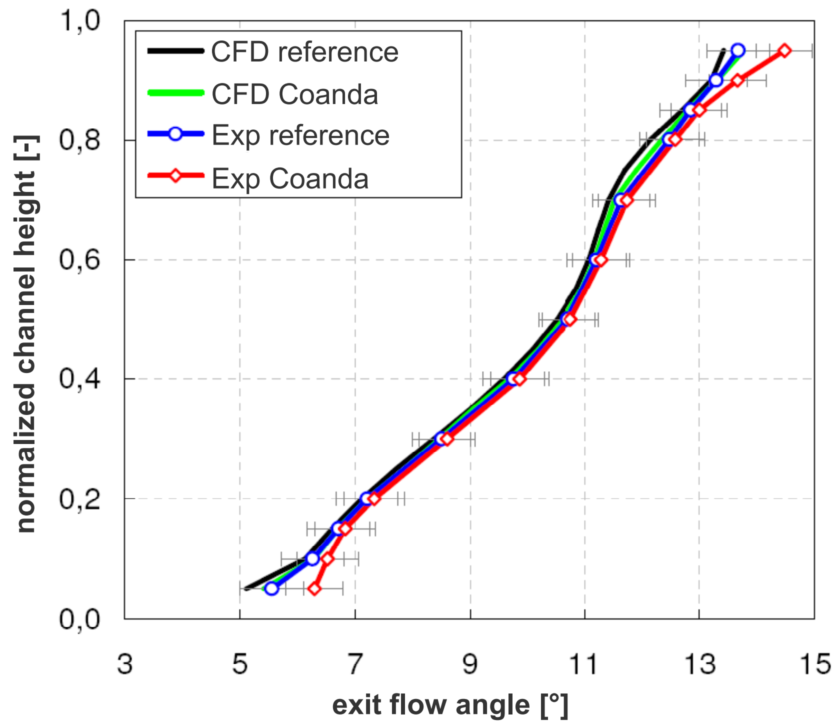
Experimental Results

Radial Distribution of the Exit Flow Angle



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AFC Stator with Coanda Surface

Conclusions

- **Turning of the Coanda-surface augmented by blowing**

  → Higher stage pressure ratio

- **0.5% of Compressor Inlet Mass Flow are sufficient to reduce vane count by 20%**

  → Reduced number of stages, reduced weight, lower investment cost possible

- **Aerodynamic performance confirmed for aerodynamic design point**

  → Increased Permissible Aerodynamic Loading by 13%

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